Fermi National Accelerator Laboratory

SDSS

Juan Estrada - Fermilab

Fermilab User's Meeting

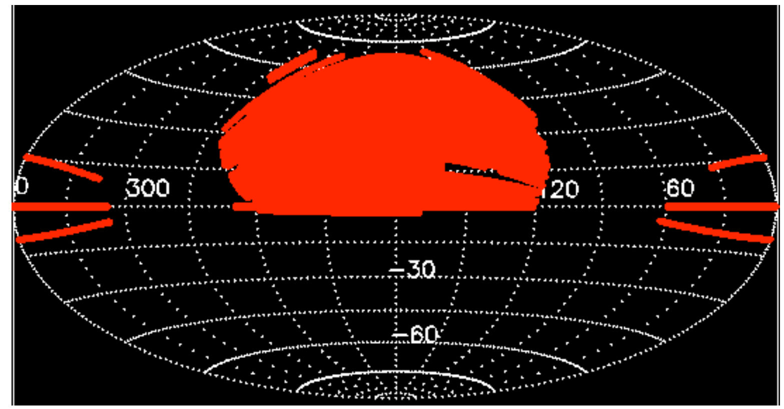
June 7, 2007

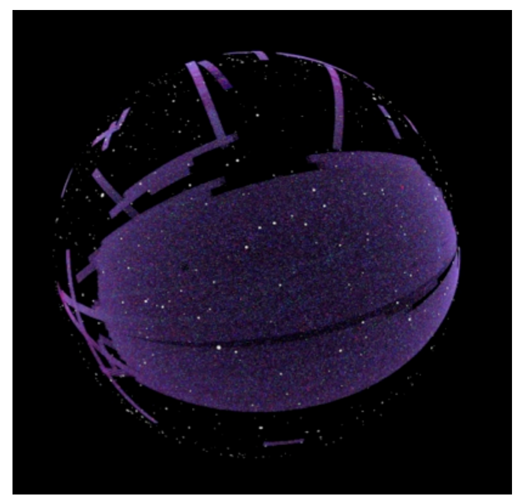
Center for Particle Astrophysics

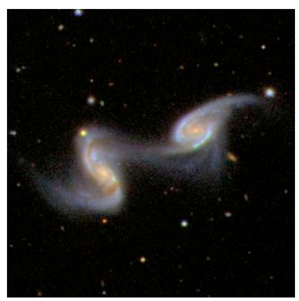
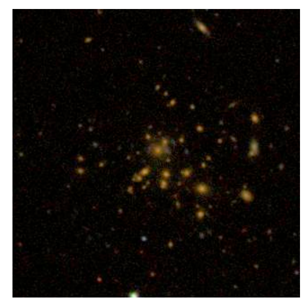
SDSS generalities

Covers ~8000 square degrees, and includes information on 132 million galaxies and 85 million stars. With 1 million spectra. **The full sky has only 41253**.

Dedicated 2.5m telescope:
imaging in 5 filters: u,g,r,i,z achieving limiting magnitudes (22.0, 22.2, 22.2, 21.3, 20.5). 120 Mpix camera. ~2% calibration errors
Spectroscopy with 640 targets at a time.
Data is public!





…is not quite google for the Universe, but gets pretty close

We will have google with the coming surveys: DES, PanSTARRS, LSST, …

SDSS II

Completed first phase of operations in June 2005 and is now in SDSS II. Which has three projects:

- **The Sloan Legacy Survey:**

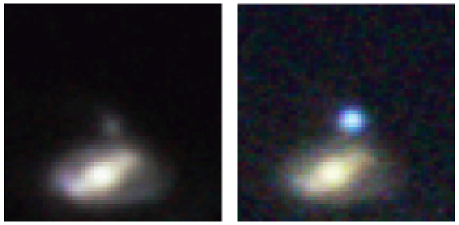
  Complete gaps in the SDSS I map (weather and other reasons)

- **Segue:**

  Map our galaxy

- **Sloan Supernova Survey:**

  Repeatedly scans a 300 square degree area to detect and measure variable objects and supernovae. Specially SNIa for cosmology.



…currently considering what to do "After Sloan 2", and investigating how to finance it.

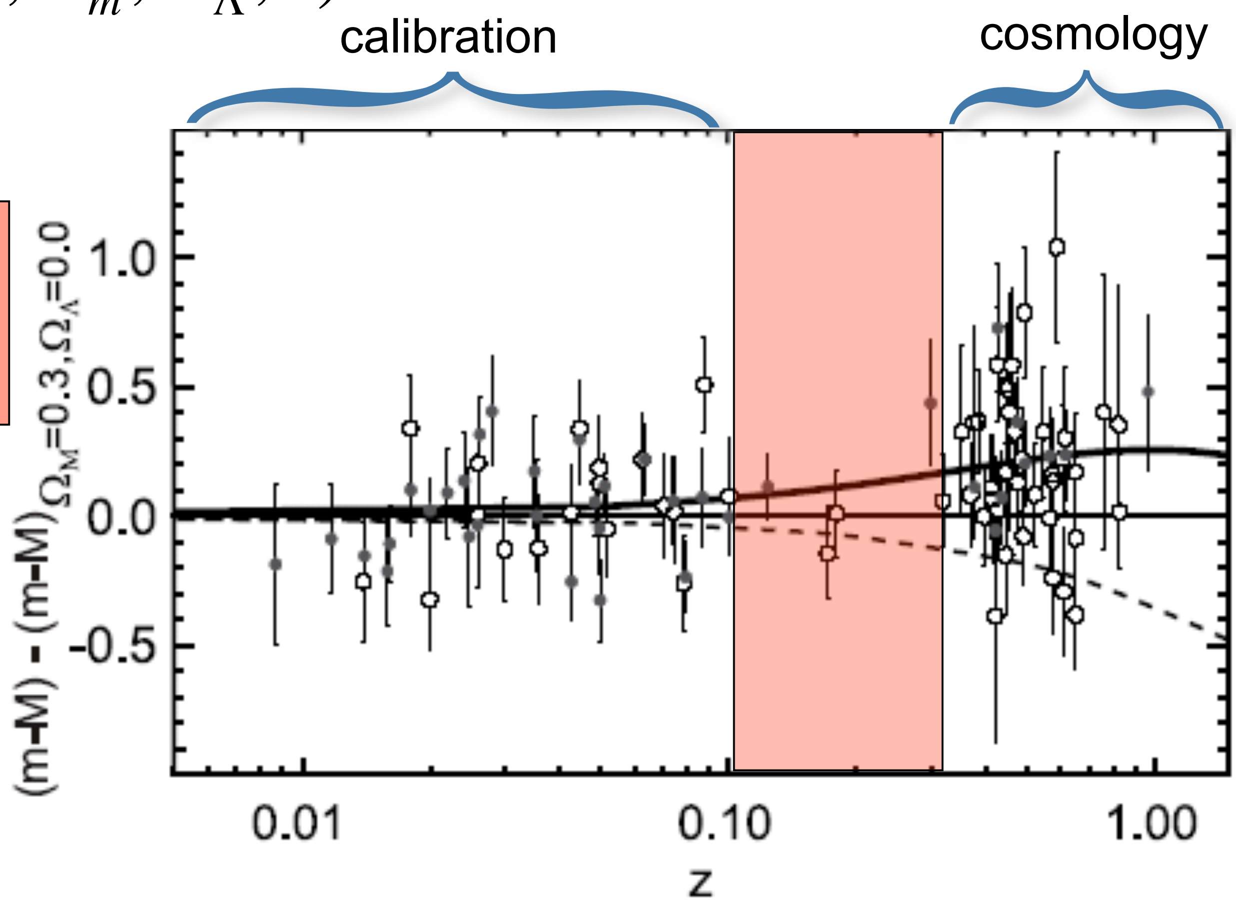
SDSS - Supernovae Ia

SNIa are **standard candles** (after some corrections). Their apparent brightness depends on distance (D_L). **The distance-redshift relation is determined by cosmology.**

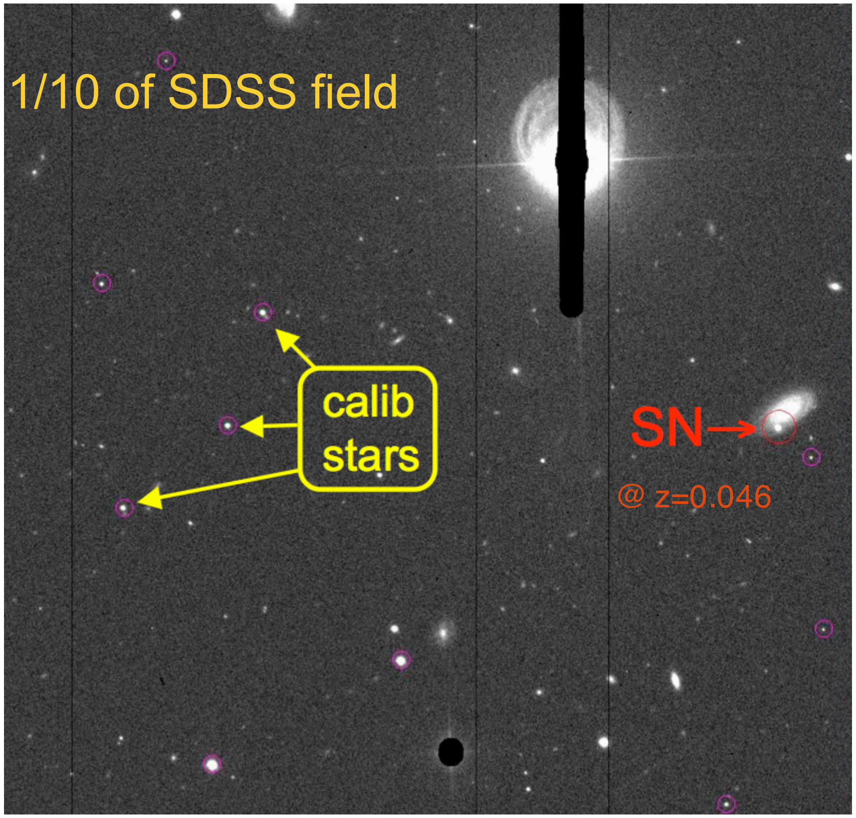
$$D_L(z) = D_L(z; H_0, \Omega_m, \Omega_\Lambda, k)$$

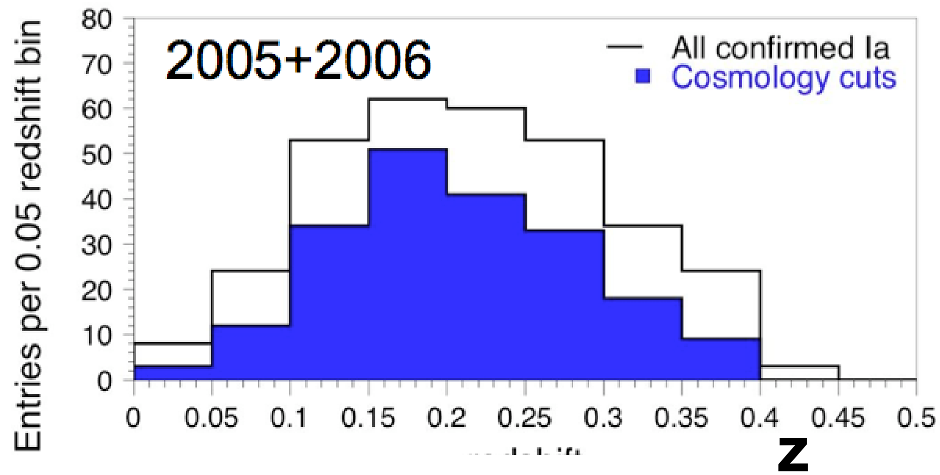
Goal for SDSS-SN

fill region 0.1<z<0.3 (redshift desert)



SDSS - Supernova





Survey:

- (2.5 x 120) 300 sq.deg, from Sep-Nov 2005-2007
- average 3.8 days between images of same object
- multifilter imaging with 2.5m
- spectroscopic follow up with other telescopes.

(this also produces deeper imaging of this region)

Yield in 2 seasons:

> 325 spectro-confirmed type Ia

- A few hundred photometric (with no spectrum), a small fraction of those with host spec

(original goal was 200 SNIa in 3 seasons) Efficient!!

Cosmological parameters fit coming soon (blind analysis)

SDSS - Segue

Sloan Extension for Galactic Understanding and Exploration

Goal:

create a 3D map of the galaxy

Survey:

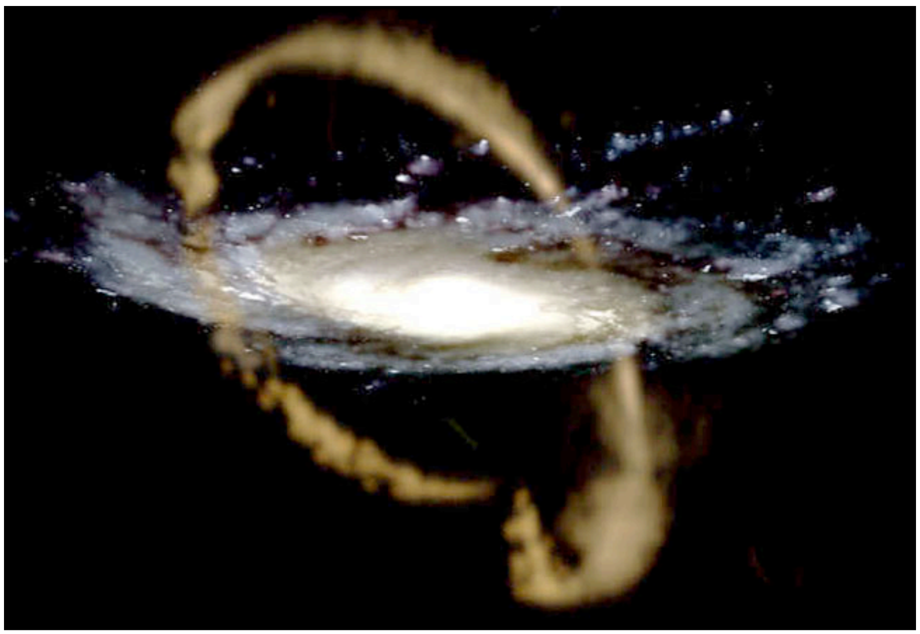
- 3,500 sq-deg of new imaging:
  - galactic plane
  - special structures like Sagittarius Dwarf Tidal Stream
- spectra for 250,000 stars

Status:

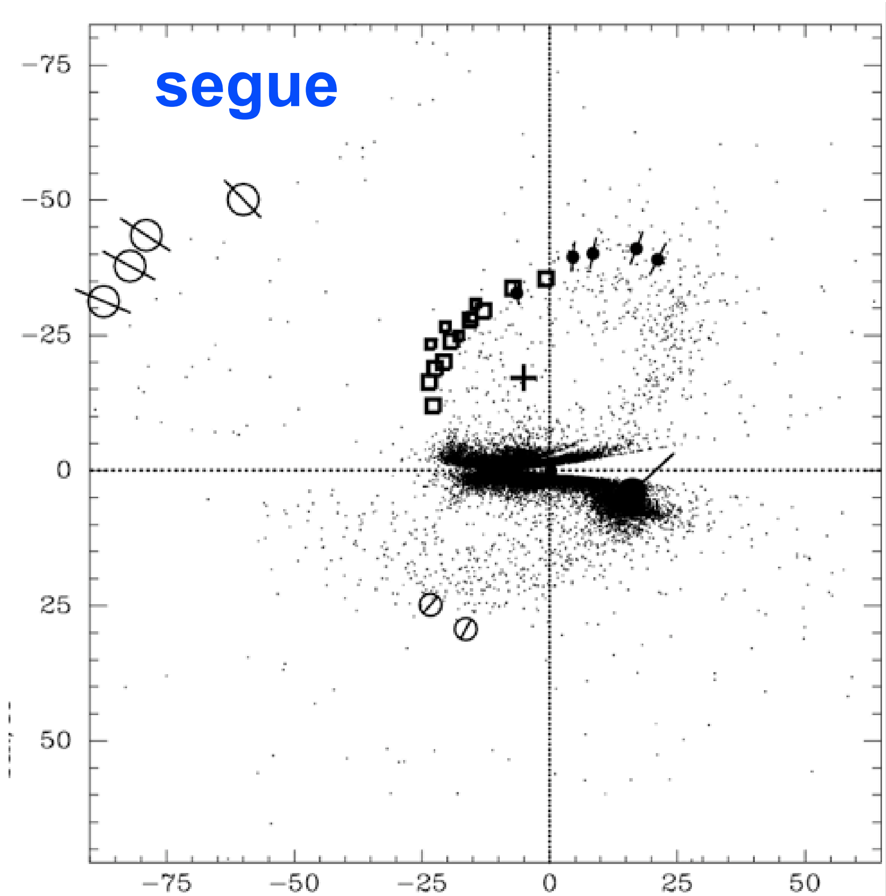
- **first public data release at the end on June 2007**
- **2/3 complete, will finish in 2008**.

Segue - science example

Milky Way Galaxy is devouring its closest satellite neighbor:
The Sagittarius Dwarf Tidal Stream
(a loose filament of stars, gas, and possibly dark matter that entangles the Milky Way).



Drawing Credit & Copyright: David Martinez-Delgado (MPIA) & Gabriel Perez (IAC)



dwarf tidal stream stars move in the dark matter halo potential, and these orbits help us to constrain the shape of the Dark Matter halo.

Cluster analysis group at FNAL

SDSS data is public. **The analysis going on is infinite**. Here I will cover only a small fraction of the total (Fermicentric).

CAG: lead by Jim Annis and Huan Lin to work on analysis of SDSS data and DES simulations. This is also an effort by Huan and Jim in the education of HEP-people to be useful for analysis of astronomical data.

Activities:

- Statistics of strong gravitational lensing around galaxy clusters
- Strongly lensed Lyman-Break Galaxies
- Weak gravitational lensing around the comma cluster
- Correlation function of galaxy clusters
- Getting ready for analysis of DES simulations

maxBCG clusters

[Optically detect clusters of galaxies]() in the SDSS data by grouping the objects by angular position and color (indicative of redshift).

One method to do this is [maxBCG]() used recently to produce a [public catalog of clusters]() (first version of this method developed by Jim Annis from FNAL).

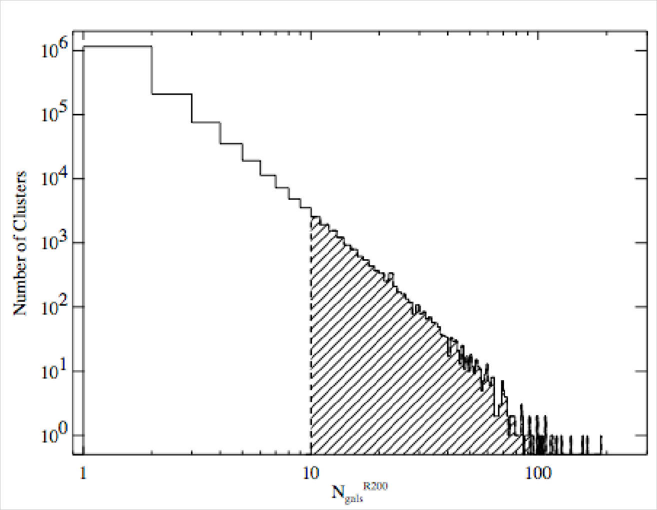
(talk by Tim Mckay yesterday)

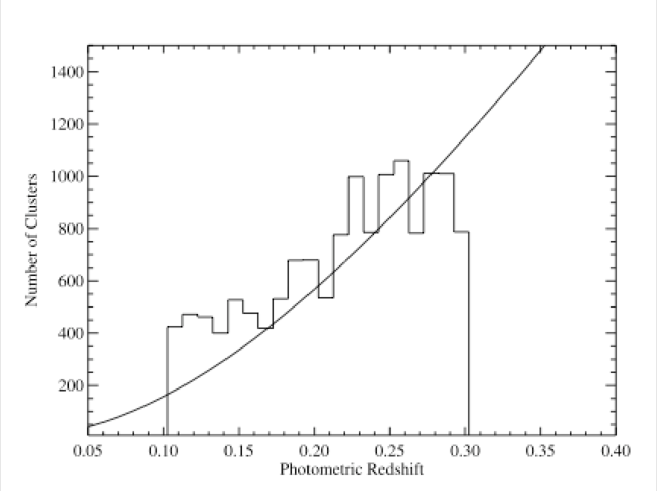
maxBCG: 0.1<z<0.3

$N_{gals} \geq 10 \rightarrow$ 13823 clusters

$N_{gals} \geq 5 \rightarrow$ 42506 clusters

Koester et al, 2007

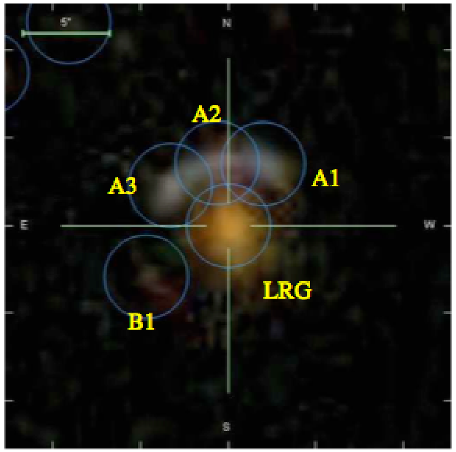




Strong lensing in clusters

Motivation:

- SDSS can see gravitational arcs
- SDSS has galaxy clusters



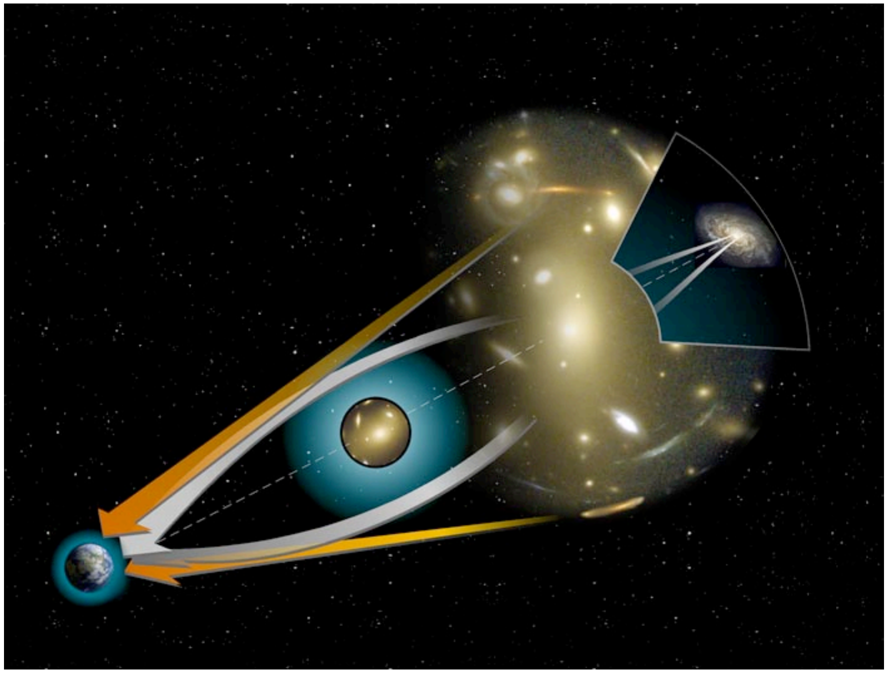
Example of SDSS arc detected by S. Allam (astro-ph:/0611138)

How many arcs are there?

Proposed as a tool for cosmology ('98), a way of measuring the clustering of matter.

Later people realized that **the lensing model is the dominant uncertainty for this**.

We did a survey of SDSS clusters to study the probability for a cluster to produce an arc. To investigate **properties of the cluster** (mass, concentration, ellipticity, others).

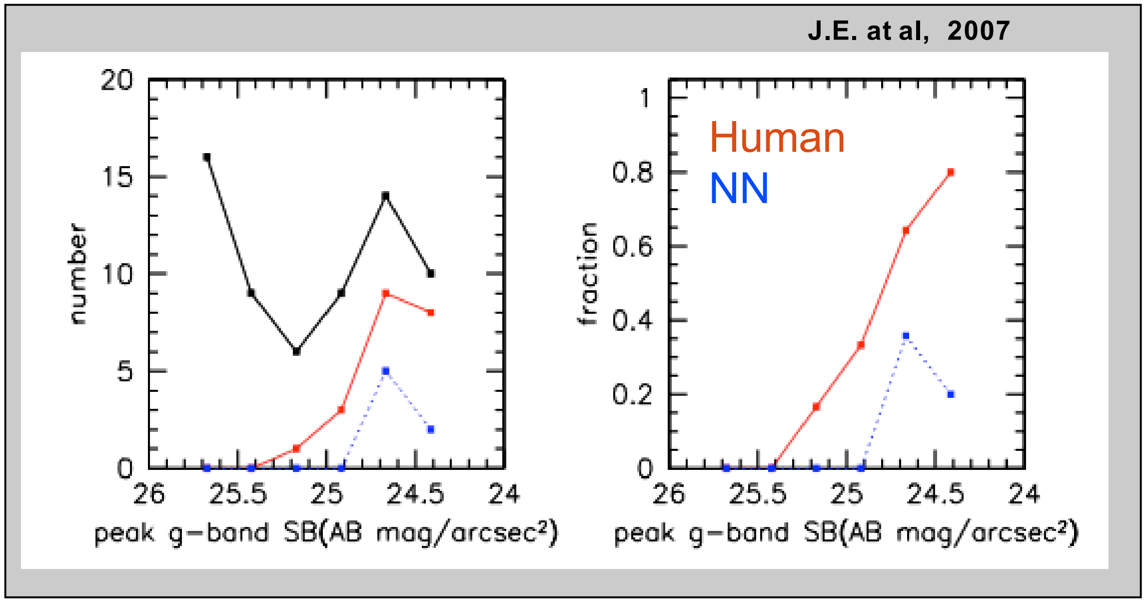


Strong lensing in clusters

Two searches on the same cluster sample (800 clusters):

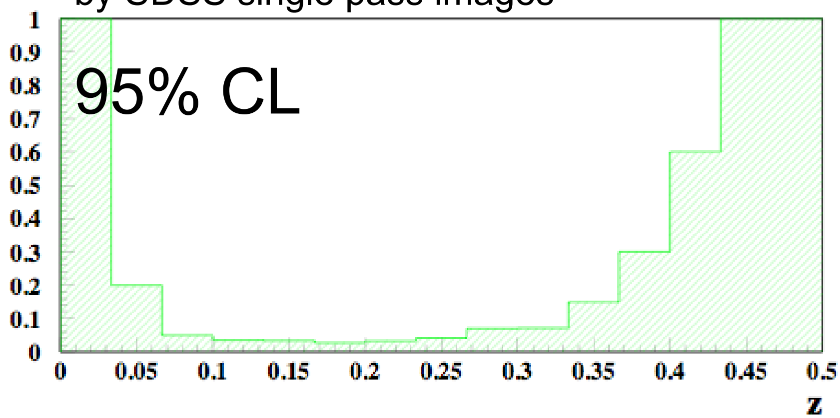
- fully automated (first time)
- human inspection

Simulated arcs were added at random to real images to measure efficiency in the detection for both methods.



No arcs detected in the sample of massive clusters.

Probability for producing an arc detectable by SDSS single pass images



Q: Why we did not see any arcs from clusters given that at higher redshifts people have seen them?

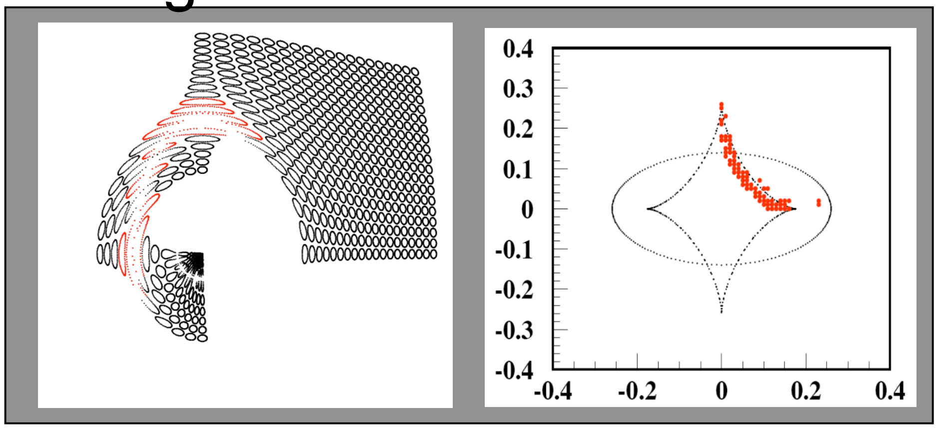
see poster by Vic Scarpine

New tools for arc detection being developed (McGinnis)

see poster by D. McGinnis

Model for strong lensing probability

Image Lens



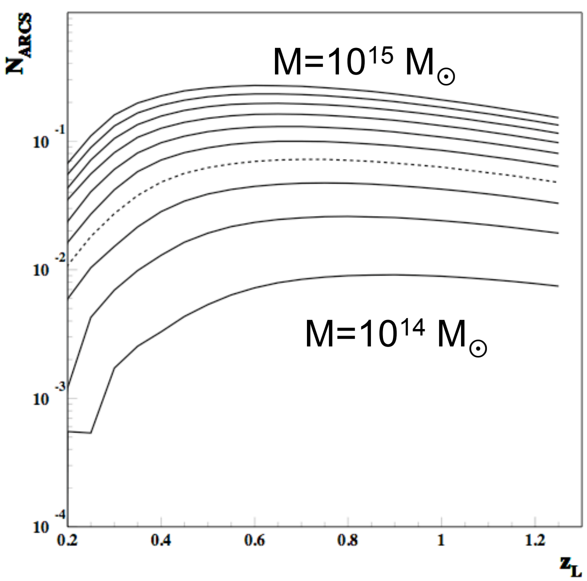
What positions of the source produce an arc-like image?

This gives a cross-section for arc production.

How does this cross section depend on redshift to the lens.

$$\sigma\left(M,c,e;z_L,z_S;R_{th},\mu_{\lim}\right)=\tilde{\sigma}\left(k_s,e;R_{th},\mu_{\lim}\right)\left(\frac{r_s}{D_L}\right)^2$$

Ray tracing combined with semi-analytic model for this study.



Using this model we show that the expected number of arcs per clusters has a **steep turn on curve**. Specially for low mass clusters.

This is consistent with the suppression of arc production rate at low redshift seen in our survey and other studies (Gladders et al). SOAR 4m proposal to confirm the predictions of this model these studies ~approved.

J.E., E. Makler, S. Mollerach, E. Roulet in preparation

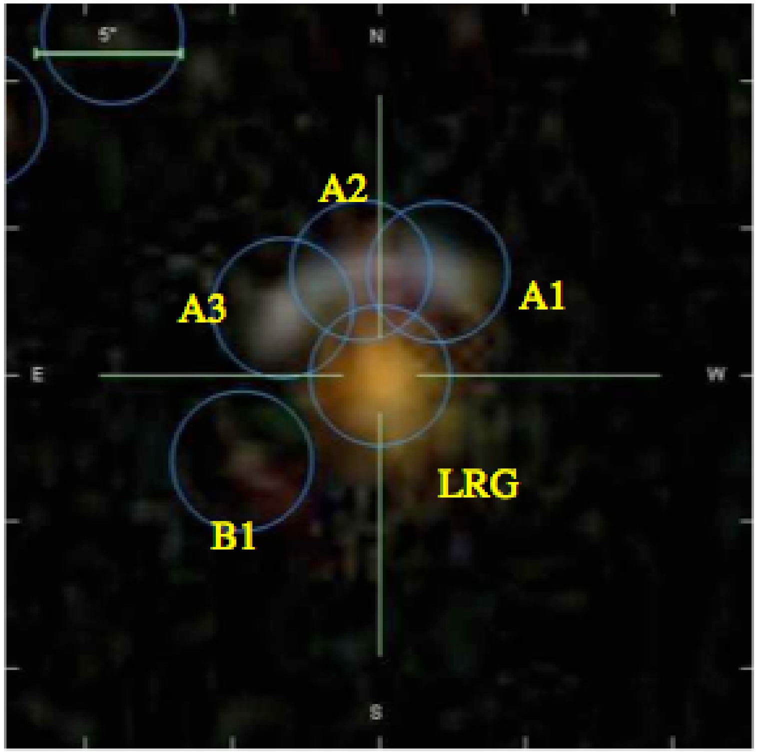
More strong lensing : now LBGs

Discovered a nice arc at 8 o'clock and decided to get spectrum. Spectroscopy was first done using 3.5m at APO (SDSS neighbor).

Turned out to be **the brightest Lyman Break Galaxy (LBG) currently known**, a galaxy at z=2.73 that is being strongly lensed by the z=0.38 Luminous Red Galaxy.

LBG : highly red shifted galaxies very faint.
In this case visible because the surface brightness is conserved:
L/W = 6
Magnified by 12.

Success prompted a dedicated search for lensed LBGs: **7 confirmed, 5 at z>2!**

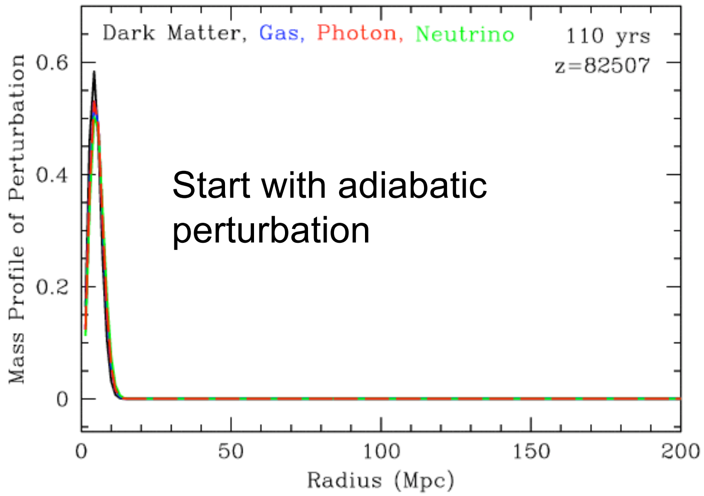


S. Allam et al astro-ph:/0611138

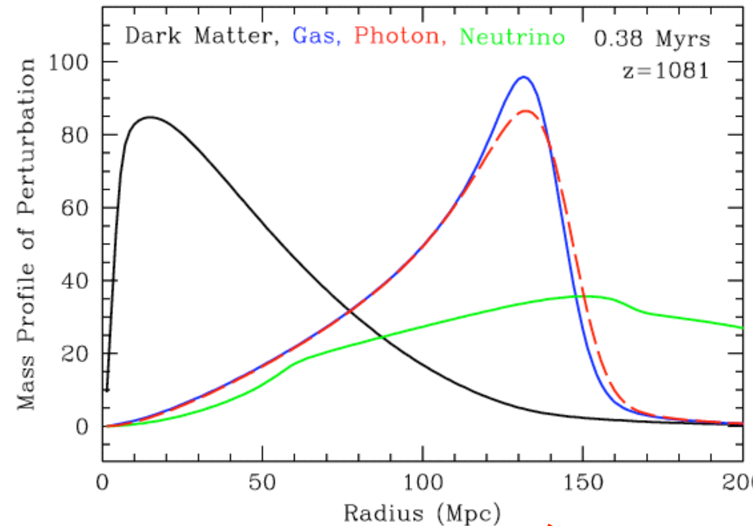
Unique window to the early Universe: Successfully applied for time on Hubble Space Telescope, Spitzer Space Telescope, and others ground based instruments. Expect exiting discoveries from a small army of collaborators.

see poster by Sahar Allam

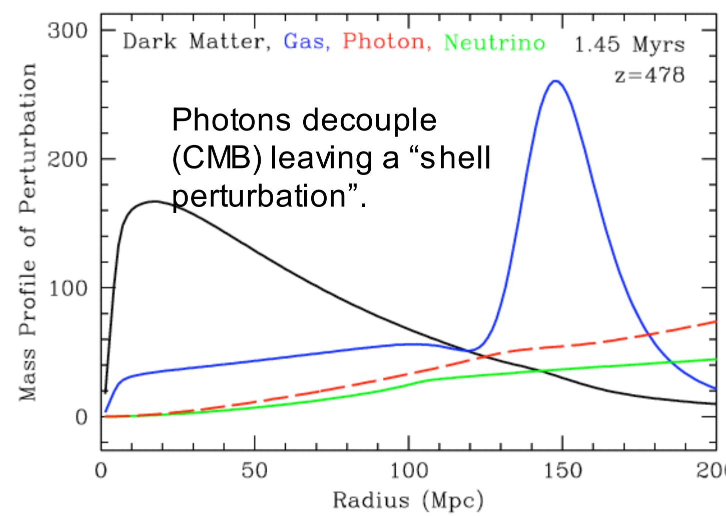
Dark matter clustering (BAO)

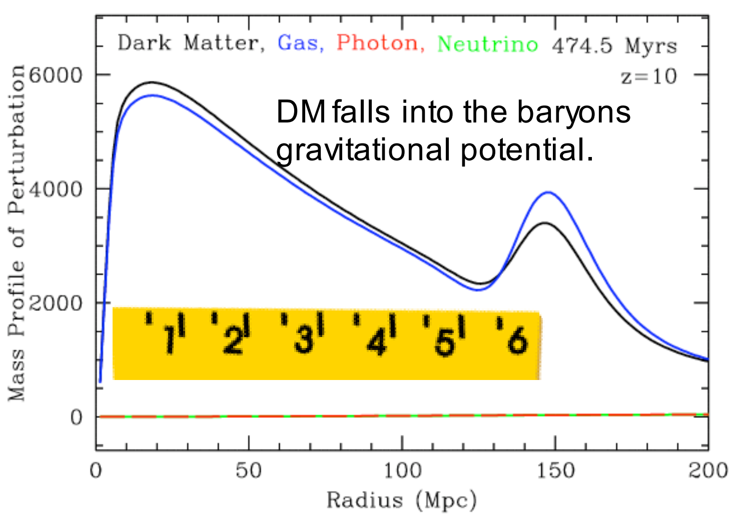


Pressure in photons produces a sound wave, gas follows.



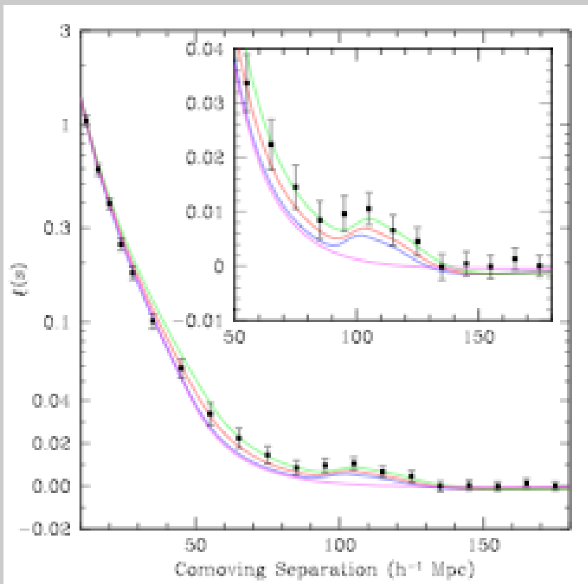
Baryon Acoustic Oscillations imprint the sound horizon scale into the DM distribution. Standard rod.





BAO detected in SDSS galaxies

47k LRGs (SDSS)



Eisenstein et al 2005

The BAO feature was detected using the sample of SDSS galaxies that have spectra.

We are now trying to see the signal using galaxy clusters without spectra.

Photo-z

Colors are used to estimate the redshift (z) of the objects imaged by SDSS.

This is applied to the galaxies and gives a precision of:

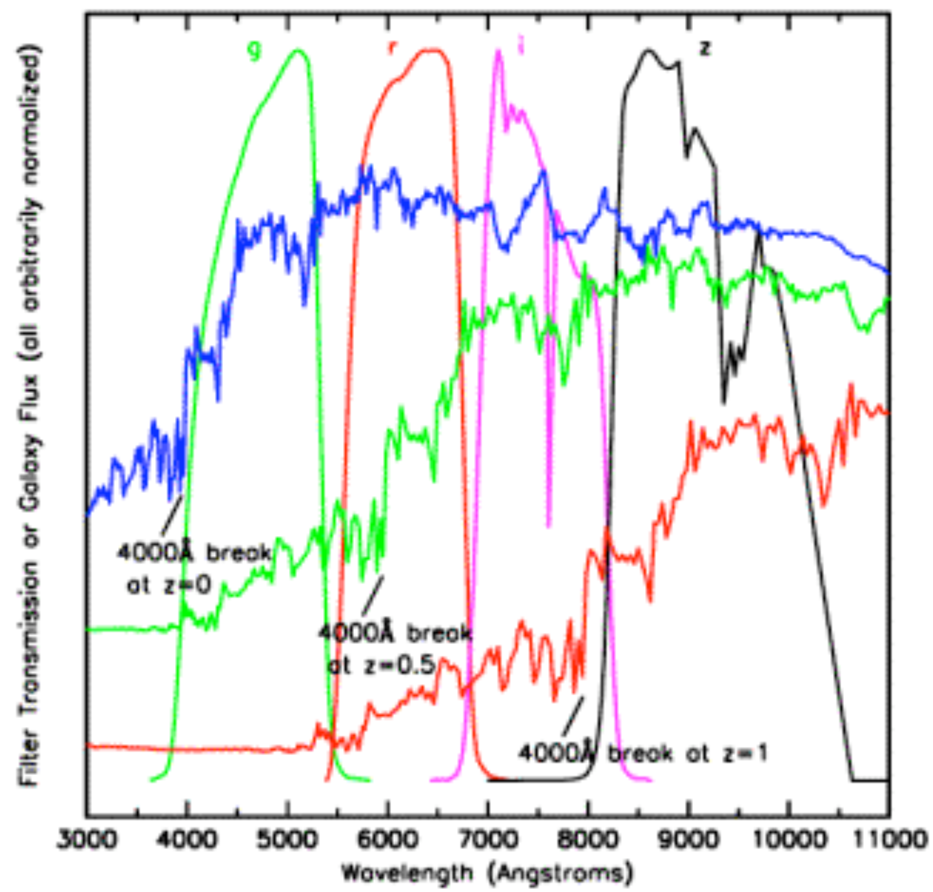
$$\sigma_z = 0.03$$

For clusters the uncertainty is smaller

$$\boldsymbol{\sigma_z = 0.01}$$

The technique is based on the 4000A break and how it moves with redshift.

In DES we will depend on photo-z.

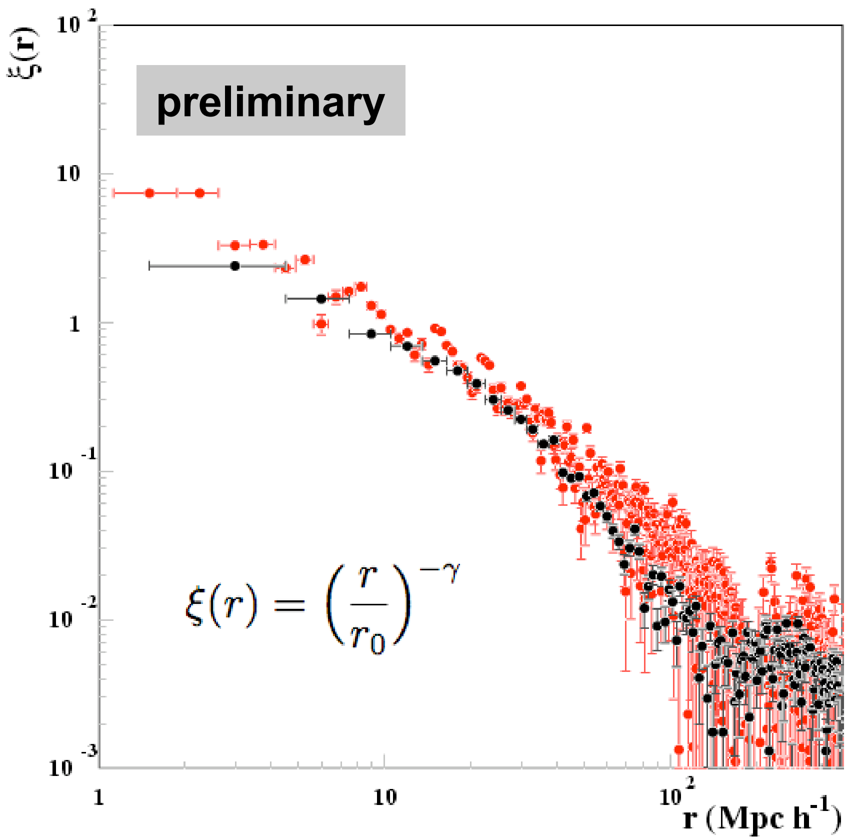


Cluster Correlation Function

Measures essentially what is the excess probability of finding a pair of clusters at a distance R compared with a uniform distribution

$$\xi(r) + 1 = NN(r)/RR(r)$$

(the estimator used is a bit more sophisticated to reduce variance)

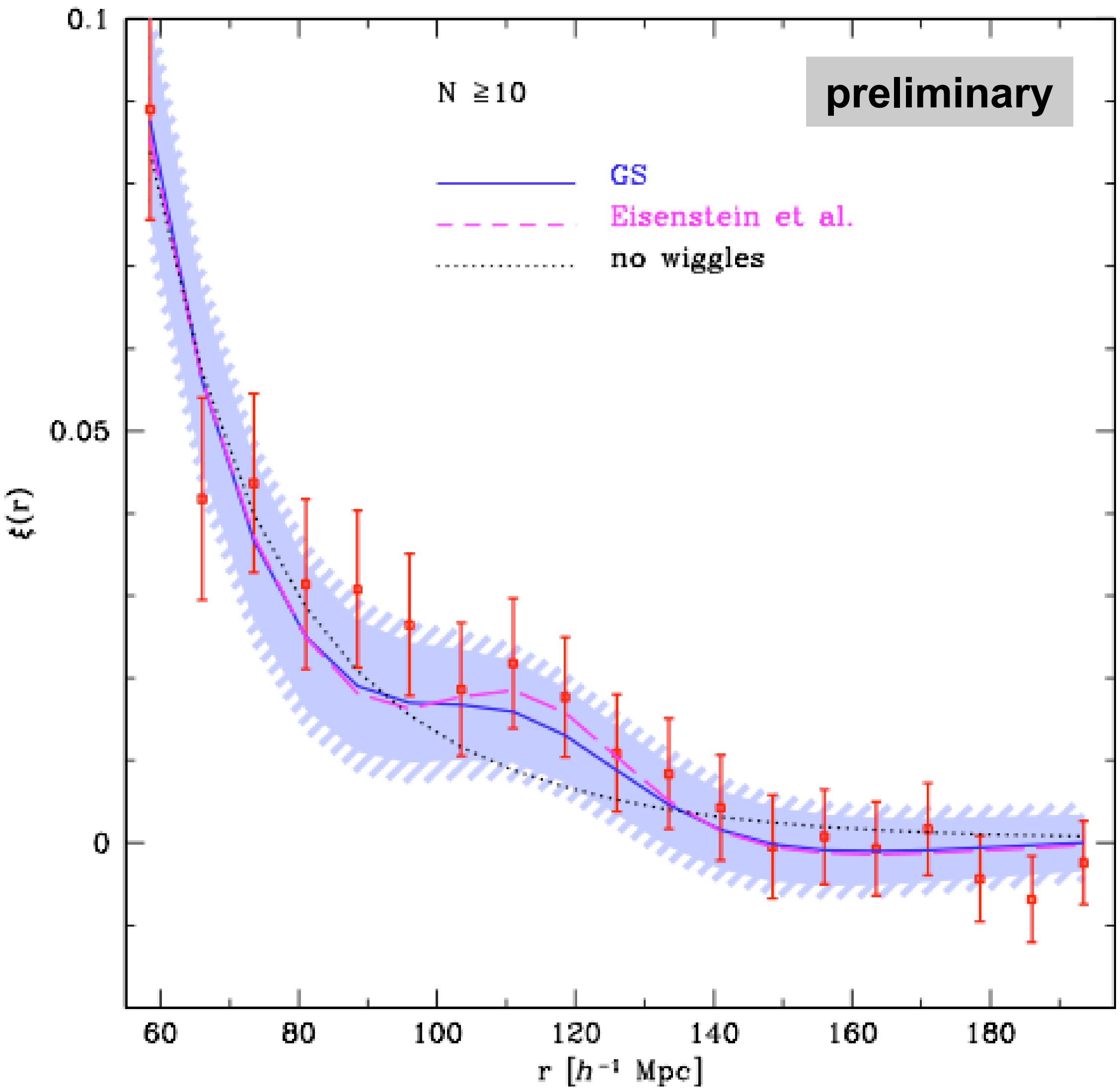


SDSS clusters $N_{gals} \geq 10$

Hubble Volume Simulation
dark matter halo catalog with **$M > 10^{14} M_{\odot}$** approximately correct for $N_{gals} \geq 10$.

r_0= 11.8 Mpc/h
γ= 1.52

BAO in Clusters Correlation Function



$N_{\rm gals}$ cut	N	r_o	γ	n	s	b	$\chi^2_{\rm BAO}$	$\chi^2_{\rm nw}$
10	13823	10.2	1.4	2.77	0.95	3.7	8.6	11.6
13	12519	10.8	1.4	2.51	0.95	3.8	7.4	11.6
15	7597	12.5	1.5	1.52	0.92	3.8	6.7	9.7
21	2766	17.3	1.7	0.59	0.92	3.9	4.9	5.9

The position of the peak is a cosmological probe. Not used here yet. Currently working in modeling the photo-z error.

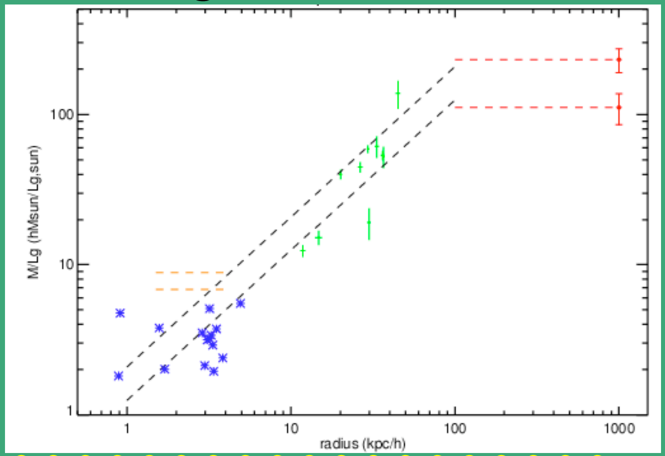
2 important aspects:

- **First detection of BAO in clusters.**
- **Shows that we can do this with photo-z.**

J. E., E. Sefusatti et al, in preparation

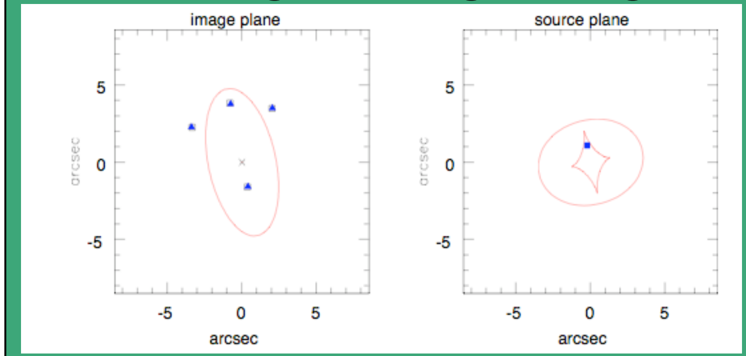
Other CAG posters

Strong lenses at SDSS



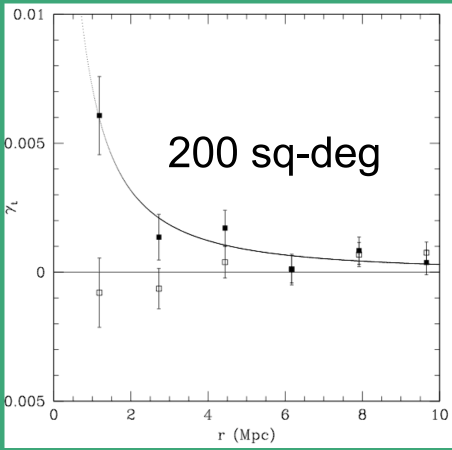
see poster by Donna Kubik

Modeling of strong lensing



see poster by Liz Buckley-Geer

Weak Lensing on coma cluster



see poster by Jeff Kubo

SDDS and HEPers

On behalf of the particle physicists working with SDSS data, I would like to **thank the Experimental Astrophysics Group, specially Jim Annis and Huan Lin, for generously spending time teaching us.**